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THE FOSSIL FLORA OF IOWA COAL BALLS

III. CORDAIANTHUS

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THE two most ancient, primitive and extinct orders of gymnosperms are known as the pteridosperms or seed ferns and the cordaites. The pteridosperms are not strobiloid because the sporangial organs are borne pinnately, not spirally or whorled. The cordaites, on the contrary, have short axes (branches) bearing a number of small, spirally disposed "strobili" or "inflorescences." In fact, the interpretation of these structures has been a controversial problem for nearly seventy years.

There have been two chief limitations imposed upon the investigation of the fructifications of the *Cordaitales*, one being the excessive rarity of structurally preserved specimens, though so-called impressions have been fairly abundant; the other limitation being the narrow point of view of the plant morphologist, who by necessity has interpreted the fossil remains. Since the cordaites possessed a construction similar to that of the coniferophyte body, it was natural that comparisons would be made with the strobili of existing coniferous and gnetalean types. Paleobotanists are endeavoring constantly to go back to antiquity and describe the earliest forms and to suspend judgment upon homologies until the extinct forms are adequately understood.

Until very recently (1938), the only structurally preserved strobili attributed to the Cordaitales were derived from the late Carboniferous (Stephanian) rocks from the region of Grand Croix, especially near Comb' Rigolle in central France. Only three or four well preserved specimens had been found elsewhere. Doctor Rudolf Florin of the Natural History Museum at Stockholm is at present preparing an exhaustive monograph of the Grand Croix material. The discovery of geologically older cordaitean strobili in American coal balls from Iowa and Kansas affords an opportunity to add considerable information toward an understanding of these ancient plants.

The Cordaitales are a natural order of extinct gymnosperms not intimately related to any existing plants, but are believed to be next-of-kin to the Ginkgoales, and somewhat more distantly to the living conifers. As far as we know, they were the first forest trees, attaining in many species a height of thirty meters or more. In general appearance, they must have closely resembled the existing conifer *Agathis*, having broad linear leaves rather than needle-like foliage.

The detached strobili of the Cordaitales are designated by the artificial form-genus name *Cordaianthus*. These strobili are monosporangiate; consequently there has been some confusion over generic and specific designations. In the older papers, the name *Antholithus* is sometimes applied to male *Cordaianthus*, though the name is also used to designate male inflorescences of other plants.

In order to introduce the terminology relevant to *Cordaianthus* and the interpretation of the strobilar construction, a new species from the late Carboniferous of the United States is here described.

Cordaianthus shuleri *Darrah sp. nov.* with five plates, twenty figures.

Inflorescence a long rigid shoot bearing monosporangiate strobili in the axils of rigid bracts. Strobili borne spirally. Strobili composed of a short stout axis bearing numerous spirally disposed bracts some of which are fertile.

Female strobilus having from one to four erect terminal ovules borne singly upon woody bracts which are tetragonal in transverse section. All of the ovules still attached in the strobili are immature, somewhat "flattened," and bilaterally symmetrical. There appears to be only one integument.

Male strobilus bearing from one to numerous (six or more) woody microsporophylls which are tetragonal in transverse section like the sterile bracts. Each microsporophyll bears six terminal erect microsporangia or pollen-sacs which are 2.2 to 2.4 mm. in length, outlined by dense "palisade" cells and containing a tissue of isodiametric thin-walled parenchyma. Pollen-grains large, ellipsoid, winged. Male gametophyte composed of many (more than twenty) cells.

Iowa: Dallas County, Waukee, Shuler Mine. 42580 (Holotype); 42468, 42471, 42472, 42473, 42474, 42581, 42582, 42585, 42586, 42603 Supplementary types (Plesiotypes). F.O.Thompson Coll.: Polk County, Walnut Township, Urbandale Mine. F.O.Thompson Coll.: Lucas County, Williamson Mines 3, 4 and 5. F.O.Thompson Coll.: Wapello County, s.w. of Ottumwa, Tillotson Mine. F.O.Thompson Coll.

Kansas: Crawford County, Frontenac. F.O.Thompson Coll.

Carboniferous: Pennsylvanian: Des Moines Series.

The type and plesiotypes are from coal known locally as number 7.

Discussion.

The diagnosis given above is based upon one hundred well preserved specimens of individual strobili and five specimens showing more than five strobili on a single axis.

These preparations were selected from slides of more than 800 different specimens represented by nearly 2200 slides. Serial sections of four strobili (three male, one female) have been made.

The largest individual strobilus which I have observed has a length of 13 mm. and a maximum width of 7.5 mm. The proportion of length to width is approximately two to one. The average size of twelve good female strobili is 10.5 mm. $\times$ 5.2 mm. The width varies considerably (3.5 to 5.7 mm.), but some distortion may have been responsible for the extremes.

The best preserved male strobilus is 11 mm. long and 4.8 mm. wide, although two good specimens are broader (10 mm. long and 6 mm. wide).

In both male and female strobili the enveloping woody bracts vary from 3.5 mm. to nearly 6 mm. in length, the average being 4.5 mm. The bracts are broad at the base, curve upwards and inwards (at least when young), and gradually taper to a narrow, sometimes pointed tip. Bracts provided with a single leaf-trace composed of a number of spiral tracheids, surrounded by crushed phloem which is miserably preserved. The trace has been termed "protostelic," but "mesarch" is more suitable.

It appears, then, that the strobilus is a very simple organ system borne in the axil of a bract. This is best shown on figure 3 which reveals a single ovulate strobilus on a short thick pedicel, the whole strobilar aggregation being axillary. Figure 1, a more mature inflorescence shows (at least in the middle strobilus to the left of the axis) a short bract.

The whole fructification, it would seem to me, is a naked branch system bearing a number of small strobili. I have before me an impression of an inflorescence attributed to *Cordaianthus gemmifer* Grand' Eury, a poorly

defined species of late Carboniferous age. The specimen in hand (number 26613, Mazon Creek, Grundy County, Illinois) shows an incomplete inflorescence 130 mm. long, bearing, near the apex, apparently spirally disposed strobili, of which forty-two are visible. At the base these appear to be nearly opposite and distichous. We have sawed the specimen transversely to the long axis, and observed at this plane only two subopposite strobili. It would seem that in this specimen the arrangement is really distichous, as conventionally described, but this is not always the case. Figure 5 shows a pair of ovulate buds lying adjacent to the axis which bears them. Leaves envelop the whole structure, but it is not possible to determine whether they were borne upon the same axis as the strobili. Figure 6 shows four ovulate strobili attached to the axis of the inflorescence. A single ovule is borne in each strobilus. Figure 7 illustrates a series of four staminate strobili, one of which is attached to the axis, a second, nearly opposite to the first, is detached in this plane but is connected below, and the other two are from a still lower series. Renault (1879, pl. 17, fig. 1) figured a specimen from Grand Croix which had five strobili attached spirally on an axis. It is certain that *Cordaianthus shuleri* has a similar arrangement of the strobili. Grand' Eury (1877, pl. 26, fig. 11) illustrated a specimen of *Cordaianthus baccifer* which shows a densely packed series of strobili arranged spirally upon a common axis.

Not much histological detail can be gleaned from our slides of the axis. The transverse sections show a nearly round, distyostelic stele, except at the nodes where the strobili and bracts arise. Here the sections are greatly elongated, and the stele presents a flattened appearance. The pith is not very extensive (0.8 mm. $\times$ 4.5 mm.) and the xylem forms a broad zone of wood. Cortical tissues are not well preserved. One can determine the nature of

the tracheids in longitudinal section: the innermost seem to be spiral, while those of the next zone (proceeding outwards) are scalariform, and those of the narrow outermost zone are pitted. It is of some interest to note that this gradation has been observed in the stems of both *Cordaites* and *Mesoxylon*.

The individual strobilus, regardless of sex, is correspondingly simple. A stalk or pedicel (figure 2) bears a large number of spirally arranged segments (figure 4), which are tetragonal, but somewhat rounded in transverse section. The stele is solid but medullates (figure 2) quickly. A single trace runs out into each segment, both fertile and sterile.

The outermost bracts are very woody (figure 10) and these envelop a large number (fifty to ninety, or more) of segments (figures 9, 12). The innermost members are slender and acicular.

Occasionally the female strobilus may bear several ovules, for example, three (figure 13). We have made serial sections of the specimen here illustrated, but the degree of preservation does not permit a full analysis of the phyllotaxic arrangement of the segments. In those strobili which bear only one ovule, the ovule is absolutely terminal and all sterile segments are placed spirally beneath it.

The male strobilus is clearer and more understandable. Each fertile segment normally bears six erect pollen-sacs which are filled usually with the partially developed pollen-grains. Figure 17 illustrates several clusters of pollen-sacs and figure 18 shows, at a greater magnification, masses of pollen from two stamens. The individual winged pollen-grains are shown in figures 19 and 20. The specimen illustrated in figure 16 shows a single strobilus with pollen in the center. In this specimen the walls of the sporangia have disappeared except at the periphery

of the mass. The mechanism for dehiscence has not been observed. It is noteworthy that the male gametophyte in the pollen-grain is multicellular, often with more than twenty cells. However, the great majority of pollen in the sacs have only five to seven cells visible.

I should like to call attention to an anomalous feature of the young shoot illustrated in figure 3. Serial sections (fourteen) through this specimen revealed only one developed strobilus on three sides of the inflorescence; the fourth side was destroyed when the coal ball was first sawn in two. However, there are the unmistakable structures of a verticillate arrangement. The vascular strands occur in series of four at approximately 90 degree angles. Attention is called also to figure 6, which might well be from the same individual, although it was cut from another portion of the coal ball. Since these two specimens are quite immature, I see no reason for placing them in a distinct species. It is possible that they do actually belong to another species, but only additional material could offer conclusive evidence.

RELATIONSHIPS.

When one attempts to compare *Cordaianthus shuleri* with other cordaitean fructifications one encounters certain fundamental difficulties. The relatively abundant preserved material from central France which shows structure belongs presumably to the stems known as *Poroxylon*. Most of the older cordaitean stems (as found in England, Germany and Holland) are distinguished by significant differences in the nature of the protoxylem and leaf traces, and are referred to the form-genus *Mesoxylon*. Strobili attributable to stems of the *Mesoxylon* type are very imperfectly known. This uncertainty is unfortunate because all of the cordaitean stems from Iowa coal balls, thus far studied, belong to *Mesoxylon*.

Cordaianthus shuleri is the only species based upon fructifications of *Cordaites* (or *Mesoxylon*) for which both staminate and ovulate strobili are known. Indeed, there are paleobotanists who would insist on giving distinct specific names to the two sexes; and this in spite of the similarity in size, construction, and histology of the two types of strobili.

Cordaianthus shuleri belongs to a species of *Mesoxylon* (4, p. 129).

In 1918, D. H. Scott reported the occurrence of special axillary shoots associated with *Mesoxylon multirame* which has a more or less flattened stele, a bilaterally symmetrical construction and a distichous arrangement of branches bearing spirally arranged bracts. In the following year, he described (18) these fertile shoots in detail and referred to them the seeds known as *Mitrospermum compressum* A. Arber (1) which, however, (despite a remarkable frequence) were not found in organic attachment. Scott was of the opinion that the dozen seeds lying near a single shoot were probably originally attached to it.

A nearly transverse section of the axis of *Mesoxylon multirame* measured 6.5 mm. $\times$ 1.5 mm. and showed a detached branch lying proximal to the main axis. In this branch the stele was round and had a large pith. Scott described each branch as receiving a small stele from the main shoot, but this stele rapidly expanded and became medullated. The bracts had a single mesarch vascular bundle. The wood of the fertile shoot consisted of spiral and scalariform tracheids, and conforms with the inner zone of wood of the ordinary *Mesoxylon* stem. This structure is in reality a *Cordaianthus*.

Scott described this inflorescence, belonging without reasonable doubt to *Mesoxylon multirame*, from the middle Carboniferous of Britain. The specimen he figured consisted of naked shoots borne in the axils of leaves. A

number of isolated specimens have also been found which show the chief morphological features of the whole inflorescence. There is a leafless main axis which bears distichous bud-like branches, and each bud-branch bears spirally disposed bracts which have a single mesarch leaf-trace. The branch possessed a ring of vascular strands. The sex of the inflorescence was not apparent because neither stamens nor ovules were preserved. On the basis of the sturdiness of the bracts, Scott suggested that it was female. Renault believed (on limited material) that the bracts of the female strobilus were thicker, more robust, and more coriaceous than those of the male. Recently Hirmer (11) has placed this fossil form in *Gothania*, a name which in my opinion is unnecessary, because it is a form-genus within a form-genus. As we have little acquaintance with the axes of the Grand Croix *Cordaianthus*, it seems undesirable to segregate certain forms of *Cordaianthus* which have an axis with a large pith or a ring of xylem bundles.

Turning now to the *Cordaianthus* from the Stephanian of central France, we find a great volume of published observations and opinions. In fact our concepts of the fructification of the Cordaitales are based exclusively on them.

The female fructification has usually been described as having stout, woody bracts (spirally disposed on the axis) with a single ovule borne on a short stalk in the axil of some of these bracts. Some years ago, Schoute (17) made a study of the phyllotaxy of *Cordaianthus zeilleri* and concluded that each organ which bears an ovule replaces a leaf; thus the ovules and their pedicels have the morphological value of very simple sporophylls. The female fructification is a strobilus, not an inflorescence.

Cordaianthus williamsoni Renault has a thick conical axis bearing spirally disposed woody bracts, in the axils

of some of which, according to Renault, were borne very short stalks with several bracteoles and terminal ovules. This species is known only by longitudinal sections. C. E. Bertrand (3) reinvestigated the female strobili of *Cordaianthus* and concluded that Renault's interpretation of these structures must be discredited. More recently, as indicated above, Schoute and Florin have proposed a simple interpretation of the ovulate strobilus.

C. E. Bertrand described the ovulate strobilus as consisting of an axis clothed completely by the bases of the bracts. The axis contains a vascular cylinder of ten strands which are separate. Each bract is supplied with a single vascular bundle which is essentially similar to a single strand of a typical vegetative leaf. The bract contains hypodermal bands of fibrous tissue.

The regrettable misinterpretation of the female strobilus has resulted in false reasoning. The ovulate strobilus accordingly has been termed compound because supposedly a fertile "branch" arises in the axil of a bract. Since a similar strobilar construction was believed to exist in the conifers, the so-called ovuliferous scale has been compared to an axillary shoot.

Scott (19) aptly said "that the data are insufficient for the interpretation of the female catkin in terms of any recent gymnospermous fructifications." It has been shown recently that if any comparison can be made, it must be with the very similar strobili of *Walchia* and its kin (*Voltziales*).

Florin (8) has also recognized the simple nature of the strobilus of *Cordaianthus* and thus affirms the opinion of Schoute. The species upon which his interpretation is based was described originally by Kidston as *Cordaianthus profluitans*, but material newly collected afforded considerable additional information. In this form, the stalks of the ovules are flattened and are similar to the

sterile bracts. He described the bundle of each bract as "protostele-like," having protoxylem in the center of the xylem mass. The seed is described as being terminal, erect and provided with a single integument.

Florin has shown conclusively in this paper that the ovulate strobilus of *Cordaianthus* and that of the extinct Carboniferous and Permian conifers of the *Walchia* type are fundamentally alike. In deference to Doctor Florin, who only preliminarily published and provisionally described these groups, I make no attempt to draw generalizations from the Iowa specimens, beyond the concept of the species.

The male fructifications have usually been described, following Renault, as a thick axis bearing spirally arranged bracts with the sex organs inserted between them. A number of nominal species have been named from structurally preserved specimens. The best known "species" is *Cordaianthus penjoni* Renault. In this form the stamens are spirally arranged and are inserted between robust, woody, acicular bracts. It is probable that the stamen is a fertile bract. Each "stamen" consists of a sporophyll (not a filament) upon which are borne six (one to six) elongate pollen-sacs (7). Pollen of this species and of another, *Cordaianthus saportanus* Renault, have been observed. They are ellipsoidal, approximately 0.09 mm. $\times$0.05 mm., and have extensive gametophytic tissue within the intine. The number of cells often exceeds thirty. Renault originally described them as having ten to twenty equivalent cells.

The strobilus, at any rate, is a simple structure sometimes interpreted as a "mixture of sterile and fertile microsporophylls." Renault described the staminate strobilus as being extremely simple, formed of only a few stamens. He believed that the entire structure was a flower. Solms-Laubach (21), later, interpreted the "sta-

men" as a flower, and the so-called filament as the "flower stalk." Thus he made comparisons with the Gnetales. All of these opinions have been rendered untenable. All of the existing gymnosperms have had long ancestries, at least into the early Mesozoic. Each group in its own manner has been modified or elaborated from simple types. It is to these simple types such as *Cordaianthus* that we must make recourse, instead of working backwards from extant forms of uncertain ancestry.

Other Cordaitean remains associated with the strobili.

It is not my intention to give a detailed description of seeds, leaves, or woods, which form conspicuous components of the large Iowa coal ball flora. Three previously described types, however, are abundant and, as they possibly belong to *Mesoxylon*, brief records of them are incorporated herewith.

Cordaites (Cordaitophyllum) cf. **crassus** *Grand'Eury.* (Figure 21).

There are a large number of cordaitean leaves in the Iowa coal balls, and these reveal considerable variability, so much so, that one is forced to accept the probability of the presence of at least several species. The example illustrated here is the most abundant. Three morphological characters are noteworthy: (1) the fairly extensive development of sclerenchymatous tissue near both the upper and lower surfaces of the leaf with much larger pointed masses projecting upwards usually, though not absolutely consistently, between every two vascular bundles; (2) the homogeneity of the parenchyma without the development of a palisade tissue near the upper surface and (3) the small mesarch vascular bundles which are surrounded by a sheath of tissue of somewhat doubtful

origin. The only described leaf which seems to be characterized by similar features is *Cordaites crassus* Grand' Eury from Grand Croix in central France.

There is some uncertainty, however, concerning the validity of the numerous species based on leaves which have been provisionally recognized. Numerous of the Iowa coal balls contain leaves that appear to be much nearer to *Cordaites felicis* Benson (2) which is most probably the foliage of *Mesoxylon multirame.* To Benson's species belong at least three and perhaps four nominal species.

Felix in 1886 (6) described three types of leaves from the Westphalian rocks of the Ruhrgebiet under the names *Cordaites wedekindi, C.loculosus,* and *C.robustus.* He had only a limited number of thin sections at his disposal and was obliged to name three distinct forms. In 1912 in an important communication, the late Dr. Margaret Benson described *Cordaites felicis.* She was able to determine much of the histology of the whole leaf. The basal portion of *C.felicis* possessed a construction similar to that of *C.loculosus* and *C.robustus.* The upper portion resembled considerably *C. wedekindi.* Benson was not able to demonstrate the specific identity of all of these forms, but Koopmans (13) has not hesitated, on the basis of Dutch material and comparative studies, to unite them into *C. felicis.* There is a point of nomenclatorial priority here which must be determined in keeping with standard procedure. Koopmans also believes that *C. weristeri* Leclercq (14) belongs to *C. felicis.*

Inasmuch as several sections from a single leaf have a strikingly variable structure, related of course to the portion from which the section was made, it seems unwise to propose a specific name for the figured specimen without qualification.

Cordaicarpus spinatus *Graham* in Bot. Gaz. vol. 97, p. 165, figs. 23, 24, 1925.

This well characterized seed was described from "longitudinal sections . . . of two seeds, and transverse sections of the half of one," from coal balls collected in the Calhoun Mine, Richland County, Illinois. McLeansboro Formation (Pennsylvanian Upper [?] Conemaugh Series). Our specimens conform in nearly all details to Graham's description.

The platyspermic seed has a very thick sclerotesta with spiny outgrowths. The type specimens have the following dimensions: 6.5 mm. long, 8 mm. wide, 3.5 mm. thick. Graham (9) reported that the fleshy sarcotesta had been almost completely destroyed in his specimens.

The example illustrated by figure 22 shows a well preserved sarcotesta and the seed measures 11 mm. in length and 5 mm. in thickness. Serial sections (eighty-three) were made from this specimen, but the exact width cannot be computed because a considerable amount of material is lost by grinding the surface of the specimen before a new peel is prepared. Another well preserved seed having almost the identical length (10.8 mm.) has a maximum width of 10 mm.

Graham's figures are not to be considered erroneous, rather they are based upon incomplete specimens. I do not propose to emend the specific diagnosis of this seed for the present, inasmuch as I am studying a young embryo of the same species.

Cordaicarpus spinatus is the most abundant seed in the coal balls from the vicinity of Waukee, Iowa (Shuler Mine and Urbandale Mine). I have seen specimens of this species also in coal balls from Frontenac and Pittsburg, Kansas. All of them were collected by or for F.O. Thompson.

Cordaicarpus species (Figure 24).

It is unnecessary to give a new name to this seed for the present, although it seems to represent an undescribed species. Dr. Fredda Reed (15) recently described, without specific name, a small cardiocarp (Bot. Gaz. vol. 100, p. 784, fig. 26, 1939) which may well be identical with the seed here reported. It shows a more or less spinous sclerotesta.

The remarkable agreement in all dimensions of the impressions with the dimensions of the complete seeds known in detail under the name *Cordaicarpus spinatus* suggests that, when histological study of the seed has been completed, it may reveal a close similarity to a *Cordaicarpus* of the *spinatus* type.

In my opinion either of these cordaicarps represents the seed of *Cordaianthus shuleri* and the implication is that perhaps both seeds are only different aspects of one and the same form.

Summary.

Cordaianthus shuleri Darrah is a new species of cordaitean fructification, referable to the stem-type known as *Mesoxylon*. Both male and female strobili are known from many specimens. Their construction is similar, and the strobili are very simple aggregations of spirally disposed segments some of which are fertile. Those female strobili which bear a single ovule have the ovule terminal. Those which bear several ovules bear them near the summit of the conical tip of the axis. The male stobilus bears a number of sporophylls each of which is surmounted by six erect, elongate pollen-sacs. The pollen bear extensive gametophytic tissue.

Attention is called to the abundant and varied detached leaves of *Cordaites* found in nearly all of the coal balls, and one type is provisionally referred to *Cordaites crassus* Grand'Eury.

Two seed types have been illustrated. One, *Cordaicarpus spinatus* Graham, has hitherto been known from incomplete specimens. A second type, unnamed, is believed to represent the external view of *Cordaicarpus spinatus*.

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EXPLANATION OF THE ILLUSTRATIONS

CORDAIANTHUS SHULERI *Darrah*

FIGURE 1. Cellulose nitrate peel of the holotype specimen showing seven strobili (male), six of them attached to the naked axis. The seventh strobilus is represented by a few bracts in the space on the right beneath the apical strobilus. ×3. Peel 8. Specimen 42580.

FIGURE 2. A single strobilus. It is the strobilus to the left of the small circle near the top of the inflorescence shown in figure 1. The medullation of the axis and the departure of a number of traces are evident. Pollen-sacs not visible. ×10. Peel 5.

FIGURE 3. A young inflorescence, showing a single ovulate strobilus, bearing an erect terminal ovule. The spirally disposed sterile segments are inserted upon a somewhat elongate branch or axis. The subtending bract is conspicuous. ×5. Specimen 42648.

FIGURE 4. A sagittal section through an ovulate strobilus. The blackened area near the top consists in part of sterile bracts and in part of integumentary tissues of an ovule. The closely inserted bracts are shown in various views. ×10. Specimen 42471.

FIGURE 5. Two immature ovulate strobili ("buds") adjacent to the circular axis which bears them, and lying between two leaves, seen in vertical sections. ×5. Specimen 42472.

FIGURE 6. A transverse section through an inflorescence, taken at right angles to the axis, showing four ovulate strobili, all attached. The strobilus at the bottom left shows an ovule with a prominent "micropylar beak." ×5. Specimen 42474.

FIGURE 7. A nearly transverse section through a staminate inflorescence. ×5. Specimen 42581.

FIGURE 8. A longitudinal section through the basal portion of the inflorescence shown in figure 7. ×5.

FIGURE 9. A transverse section through an immature staminate strobilus, showing the enveloping bracts around the periphery, and the more acicular bracts near the center. ×10. Specimen 42473.

FIGURE 10. External view of a strobilus (sex undetermined) showing the woody bracts. Exposed from matrix. ×10. Specimen 43316.

FIGURE 11. Immature staminate strobilus, peel taken along a longitudinal median plane. Axis cut slightly diagonally. ×10. Specimen 42473.

FIGURE 12. Transverse section through the basal portion of an ovulate strobilus, just below the region of coalescence of the ring of woody bundles in the medullated portion of the strobilar axis. ×10. Peel 52. Specimen 42603.

FIGURE 13. Transverse section through the same specimen showing three ovules, one (upper right) broken in this peel. Poorly preserved sclerotesta and sarcotesta not yet differentiated. ×10. Specimen 42603.

FIGURE 14. Sagittal section through a staminate inflorescence showing seven strobili, the middle one showing the "siphonostelic" axis of the strobilus. ×5. Specimen 42586.

FIGURE 15. Sagittal section through another staminate inflorescence with three strobili. The one to the right showing the axis of the strobilus and the one to the far left with masses of pollen. ×5. Specimen 42582.

FIGURE 16. Transverse section through a staminate strobilus bearing a dense mass of pollen in the center. The pollen represents three "stamens" (eighteen pollen-sacs). ×10. Specimen 42581.

FIGURE 17. Diagonal section through a staminate strobilus showing pollen-sacs crowded with pollen. ×10. Specimen 42585.

FIGURE 18. Pollen-sacs of the specimen shown in figure 17. ×64.

FIGURE 19. A single winged pollen-grain, not fully developed, dorsal view. ×250. Specimen 42585.

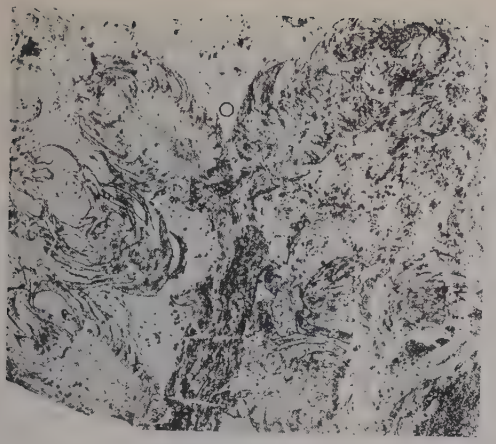
FIGURE 20. Two pollen-grains, dorsal view. Multicellular gametophyte indicated by presence of cell walls in the central body. ×250. Specimen 42585.

FIGURE 21. *Cordaites* cf. *crassus* Grand' Eury.
Portion of a leaf in vertical section, showing the parallel mesarch vascular strands and the sclerenchymatous tissues near the upper and lower surfaces. ×10. Specimen 43686.

FIGURE 22. *Cordaicarpus spinatus* Graham.
Side view (slightly diagonally) through a seed, showing the spinous sclerotesta and the fleshy sarcotesta. Cut sagittally beyond the micropyle. ×5. Specimen 39805.

FIGURE 23. *Cordaicarpus sp.*
A "front" view of a broken seed showing the endosperm body in the center, and the sclerotesta and sarcotesta on the outside. The round body near the upper left is an unnamed seed. ×5. Specimen 39805.

All figures, except 10 and 23, are from photographs of cellulose nitrate peels. These heliotype reproductions may be examined with a hand lens.



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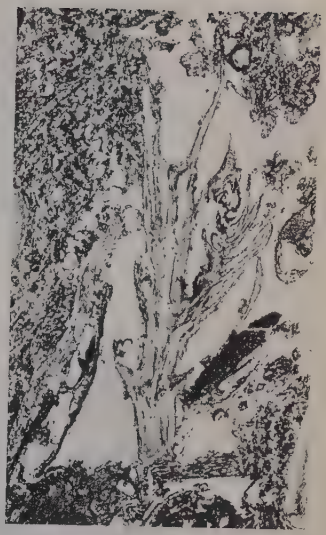

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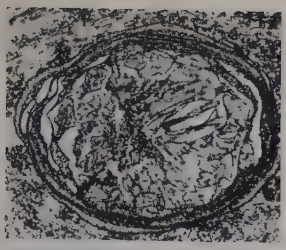

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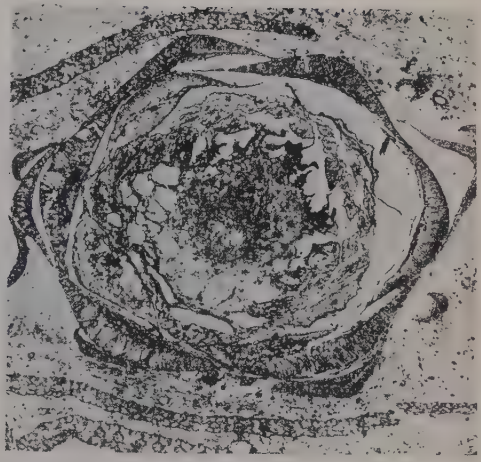

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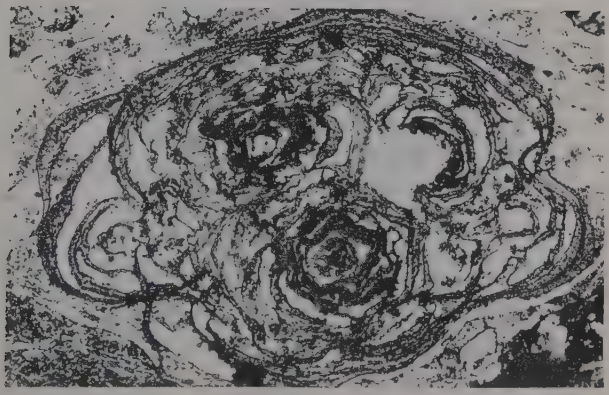

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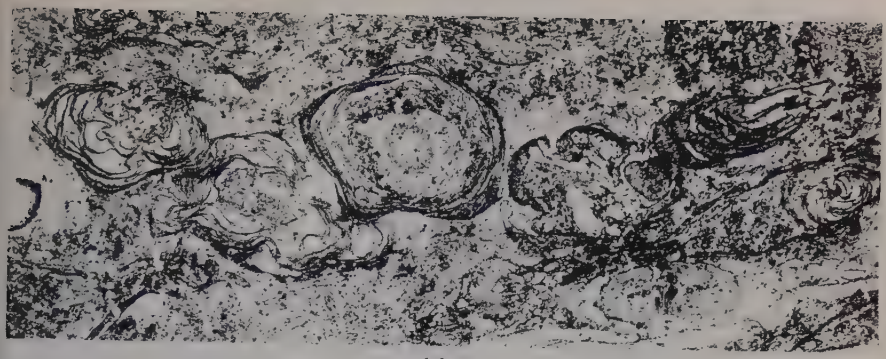

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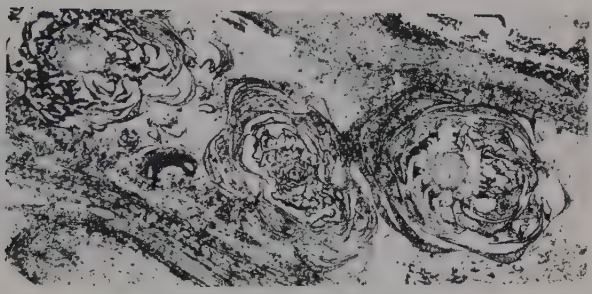

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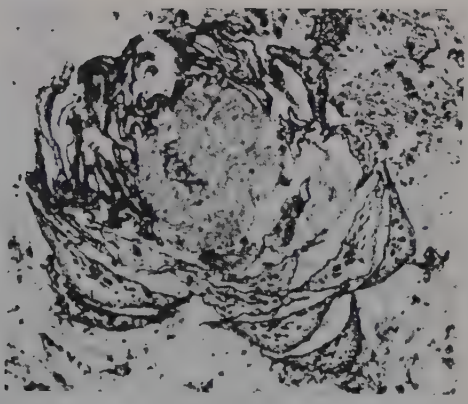

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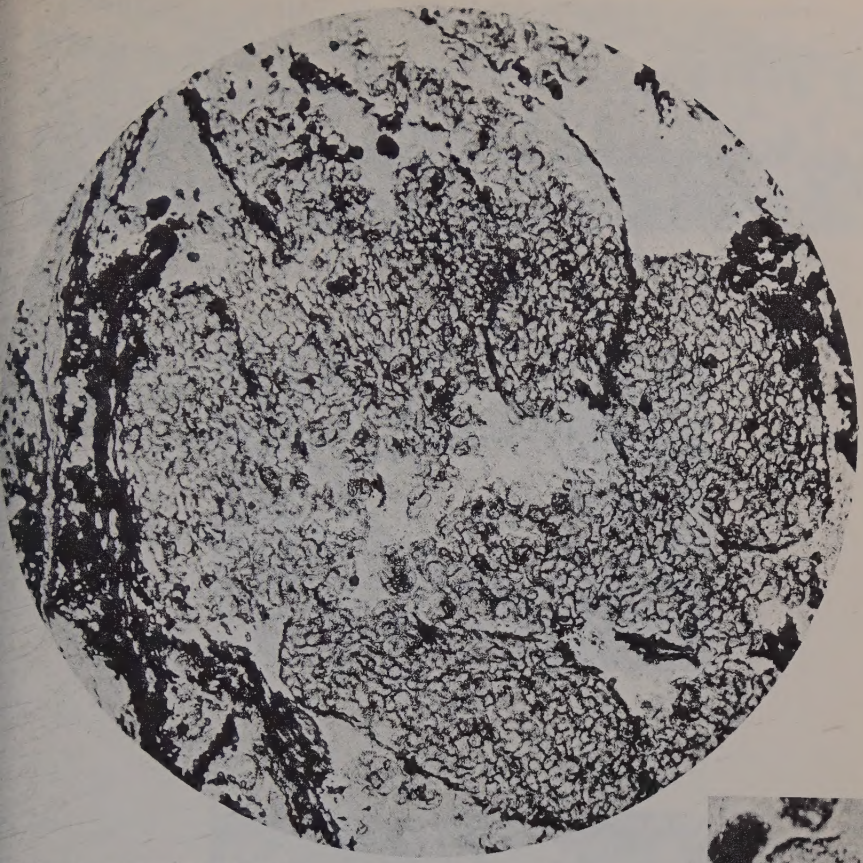

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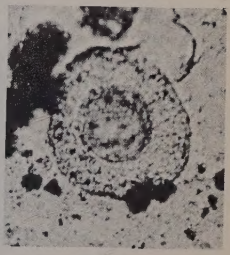

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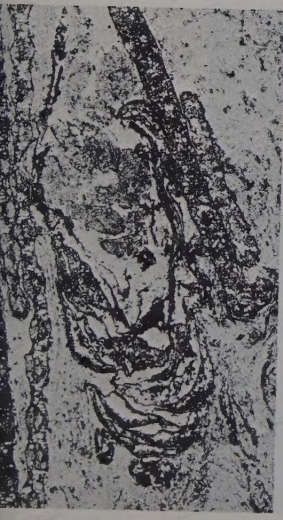

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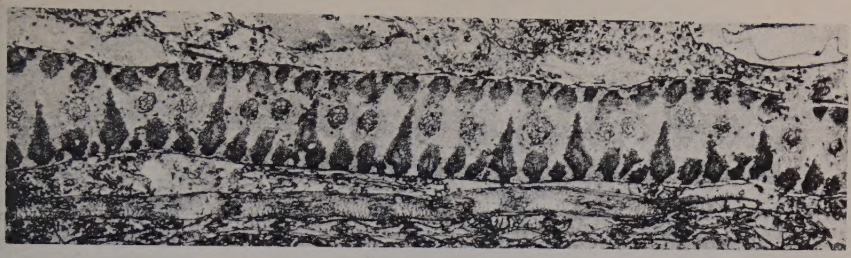

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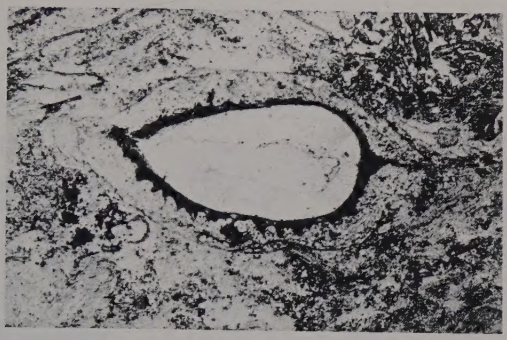

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